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SPECIFICATION ANION ADSORBING CARBON  
MATERIAL, AS WELL AS MANUFACTURING METHOD AND  
MANUFACTURING FACILITIES FOR SAME

**BACKGROUND OF THE INVENTION**

Technical-**1. Field of the Invention.**

**[0001]**

This invention relates to an anion adsorption carbon material for adsorbing anions such as nitrate ions and fluoride ions, as well as a manufacturing method and a manufacturing facilities for the same.

**2. Description of Related Art.**

**[0002]**

**Background Art**

Contamination of a-water quality and soil by heavy metals, agricultural chemicals and an organochlorine compounds has become a problem in that it destroys the environment. Though these harmful substances can be adsorbed and removed with adsorbents such as activated carbon and a zeolite, it is presently difficult to treat nitrate nitrogen, nitrite nitrogen, fluorine, arsenic and cyan which exist in the form of anions with adsorbents.

**[0003]**

—That is to say, nitrate **Nitrate** nitrogen and nitrite nitrogen are **usually** included in fertilizers used in tea fields, turfs for golfing and the like, and have become a factor in ground water contamination, which is presently a large problem. This is because nitrate ions and nitrite ions have **a** negative charge and do not become **an** insoluble salt by combining with other chemical substances, and therefore, very easily ~~washes~~ **wash** out from negatively charged soil. Thus, ~~though~~ **although** measures against the above described problem are **frequently** required, there are **practical** limitations, such that anaerobic conditions are required in biological treatment where, for example, denitrifying bacteria are used to remove nitrate ions and nitrite ions, and in addition, there are similar limitations with other methods. ~~Thus, and no~~ **completely** effective measures have been found. On top of this, recently, it has come to be believed that nitrate nitrogen and nitrite nitrogen are **possible** environmental hormones.

**[0004]**

In addition, fluorine is included in wastewater from semiconductor factories, glass factories, plating factories and the like, and ~~though~~although a method for adding calcium compounds to fluorine in industrial wastewater so that the fluorine can be removed in the form of calcium fluoride ~~is~~has been used, further installation of adsorption towers having an anion exchange resin for active alumina and fluorine is required, thereby raising the cost. In addition, expensive dedicated anion exchange resins are required in order to meet ~~the~~governmental regulations such as a Japanese environmental standard of 0.8 mg/L. Furthermore, expensive anion exchange resins are separately required for treating arsenic, cyan and the like, ~~which are included~~also found in industrial wastewater and ground water.

**[0005]**

As described above, no inexpensive material for adsorbing anions including nitrate ions as ~~that~~-described above have been found at present, and therefore, contamination by these anions ~~tend~~tend to spread, and once the environment is contaminated by anions as described above, high cost becomes necessary to restore it. ~~Patent Document 4;~~ see Japanese Unexamined Patent Publication H10 (1998)-165824

## **SUMMARY OF THE INVENTION**

**[0006]**

~~Disclosure of the Invention~~

~~Problem to be Solved by the Invention~~

Therefore, inexpensive and environmentally friendly anion adsorbing materials ~~have been sought~~are needed. Though charcoal, which is a representative porous material, together with activated carbon, is widely used as a humidity controller, ~~river~~water purifier and soil conditioner, and is used for removing chlorine based gases and sulfur oxides in waste gas, for example, it simply uses the adsorptive properties of micro pores inside the porous carbon materials, in the same manner as activated carbon, and nitrate nitrogen, nitrite nitrogen, fluorine, arsenic, cyan and the like which exist in the form of anions are barely absorbed.

**[0007]**

—This ~~Our~~ invention is ~~provided taking~~ **has taken** the above described situation into consideration, and ~~it is~~ an object thereof is-to provide an anion adsorbing carbon material which is inexpensive, environmentally friendly and excellent in ~~the~~-anion adsorption, as well as **providing** a manufacturing method and a manufacturing facilities for the same.

**[0008]**

Means for Solving the Problem

—Then ~~The~~ present inventors examined the anion absorbing performance of a material gained by contacting a solution including calcium ions (it is desirable for calcium ions to be included mainly as cations), for example, a solution (~~such as~~ lime water) or a suspension (~~of~~ milk of lime) of a calcium hydroxide with a raw material which comprises plant(s), in advance, that is, before carbonizing this material, so that Ca (calcium) is introduced into this material, ~~after that,~~ carbonizing, **The impregnated material is then carbonized so that** this material into which Ca has been introduced and contacting the gained **resultant** charcoal, into which Ca has been introduced, with an acid such as HCl, H<sub>2</sub>SO<sub>4</sub> or the like, and as a result, found that the material **resultant product** had excellent anion adsorption ability. In addition, ~~in this case,~~ wastewater **is can be** treated simply by neutralizing the acid, which is environmentally friendly.

**[0009]**

As ~~the~~ a solution including calcium ions, a calcium acetate solution, a calcium chloride solution and the like can be ~~also~~ **used**, in addition to lime water and milk of lime, ~~and a~~ solution including 0.03 weight % to 30 weight % of calcium, preferably 0.1 weight % to 7.0 weight %, is appropriate.

**[0010]**

As ~~the~~ a method for contacting the solution including calcium ions with the above described material originating from plant(s), **such as a plant material of one or of a plurality of mixed plant material, by** dripping, application, spraying, atomizing or the like of the solution including calcium ions is possible, and immersion of the above described material in the solution including calcium ions is most efficient. In addition, as ~~the~~ a method for contacting the acid solution with the carbonized material, dripping, application, spraying, atomizing or the like of the

acid solution is possible, and immersion of the carbonized material in the acid solution is most efficient.

**[0011]**

Thus, a manufacturing method for an anion adsorbing carbon material ~~according to Claim 1~~ is **can be** characterized in that a raw material which comprises plant(s) is contacted with a solution including calcium ions, and after that, **is processed to be** carbonized, and subsequently, contacted with an acid solution.

**[0012]**

In addition, a manufacturing method for an anion adsorbing carbon material ~~according to Claim 2, that~~ **is provided. That** is, another aspect of the invention, is characterized in that a raw material which comprises plant(s) with which a solution including calcium ions have **been** contacted **is then** carbonized and the carbonized material is contacted with an acid solution.

**[0013]**

Furthermore, ~~a manufacturing method for an anion adsorbing carbon material according to Claim 3, that is, still another aspect of the invention,~~ is characterized in that a carbonized material gained by carbonizing a raw material which comprises plant(s) with which a solution including calcium ions have **been** contacted is contacted with an acid solution.

**[0014]**

As the **base** material originating from plant(s) in this invention, though any plant ~~can~~ **could** be applied, a material of one or more from among natural fibers and ligneous materials, which makes the carbonized material of the above described material porous, is desirable, and any type of ligneous material, such as thinning, lumber and waste wood, as well as natural fibers such as hemp, can be cited as examples. In the case where a solution (for example, lime water or milk of lime) barely including anions (for example, chloride ions) that can be ion exchanged with anions that are the object of adsorption and including calcium ions ~~is~~ **can be** used as the solution with which the above described material is contacted,   

**[0015]**

**However,** it is desirable for the above described material to be a material where innumerable particles of a calcium compound having a diameter of no greater than 100 nm are

formed in the micro pores of a carbonized material when the material is carbonized after calcium has been introduced, and ~~concretely~~, it is preferable to use ligneous chips of a size of no greater than 10 mm gained by processing a conifer, such as Japanese cypress or cedar having a high water absorbency.

**[0016]**

In addition, in the case where a solution (for example, a calcium chloride solution) including both anions (for example, chloride ions) which can be ion exchanged with anions that are the object of adsorption and calcium ions is used, it is desirable for the solution to easily soak into the above described material when the material is immersed in the solution, and ~~concretely~~, it is preferable to use ligneous chips of a size of no greater than 50 mm gained by processing a conifer, such as Japanese cypress or cedar having high water absorbency.

**[0017]**

Furthermore, whichever solution is used, bamboo, sawdust, chaff, coconut palm, betel-nut palm, jute and straw can be used as the material originating from plant(s). In addition to these, agricultural waste, such as peels and pulp from mandarin oranges and apples, can be cited as the above described material originating from plant(s). In addition, the portion of plants having conductive tissue (vessels, tracheids and sieve tubes) are particularly preferable as the material originating from plant(s).

**[0018]**

In this invention, a solution including calcium ions, for example, lime water or milk of lime, contacts with a raw material which comprises plant(s). When the above described material is immersed in the solution including calcium ions, the solution soaks into the material, and thereby, chips into which Ca has been introduced can be ~~gained~~produced.

**[0019]**

In particular, in the case where an alkali solution (for example, lime water) is used as the solution including calcium ions, as shown in Fig. 7(A), ligneous chips 2, which are an example of a raw material which comprises plant(s), can be immersed in and is contacted with lime water C, so that chips 30 into which Ca has been introduced [see Fig. 7(C)] can be gained, and this is considered to be because, as shown in Fig. 7(B), organic matter in ligneous chips 2 is dissolved in alkali, and calcium ions react with a certain component of ligneous chips 2. Here, it is

preferable for the solution including calcium ions to contain 0.03 weight % to 30 weight % of calcium, and it is more preferable for it to contain 0.1 weight % to 7.0 weight %.

**[0020]**

Next, in this invention, the gained chips 30 into which Ca has been introduced as described above [see Fig. 8(A)] are carbonized, and thereby, charcoal 31 into which Ca has been introduced (hereinafter simply referred to as Ca charcoal) is gained [see Fig. 8(C)], and it is considered that at this point during carbonization, organic matter in chips 30 into which Ca has been introduced [see Fig. 8(B)] decomposes due to heat, and at the same time, calcium ions deposit on the surface of the walls of micro pores in chips 30 into which Ca has been introduced [see Fig. 8(C)]. In this case, calcium ions deposit on the surface of the walls of micro pores in chips 30 into which Ca has been introduced [see Fig. 8(B)], and this is considered to be because calcium ions become of a microscopic and highly dispersed state, and thereby, many functional groups ~~are~~can be drawn out from every corner in the walls of the micro pores.

**[0021]**

~~———In this invention, a raw material which comprises plant(s) which has been contacted with a solution including calcium ions is carbonized, and after that, an acid solution contacts with~~An acid solution can contact this carbonized material, and thereby, functional groups which have been drawn out from the walls of micro pores in the carbonized material are combined with anions which can be ion exchanged with anions that are the object of adsorption. As a result of diligent research, the present inventors found that more functional groups of the carbonized material can be generated during the process of carbonization by controlling the temperature and the time period.

**[0022]**

That is to say, the present inventors ~~confirmed that in the case where calcium has contacted with a material as that described above in advance, as in the invention according to Claim 1, and the material is~~material can be cooled naturally after ~~the~~a temperature for carbonization of 650°C to 750°C has been maintained ~~for~~, for example, for one hour, more functional groups can be formed, in comparison with ~~the~~a case where the material is cooled naturally after the temperature for carbonization of approximately 600°C or approximately 800°C has been maintained for one hour. In particular, when a material was contacted with a calcium and

carbonized at a temperature for carbonization of 650 °C to 750°C as described above, and observed through an electron microscope, a state where microscopic particles of the calcium compound ~~half~~were deposited on the surface of walls of the micro pores as described above and were uniformly dispersed was observed.

**[0023]**

——~~Meanwhile, when~~When the temperature for carbonization was approximately 600°C, a state where microscopic particles of a calcium compound did not sufficiently deposit on the walls of the microscopic pores as described above was observed. In addition, when the temperature for carbonization was approximately 800°C, though deposition of microscopic particles of a calcium compound on the walls of the micro pores as described above was observed, the state was such that there were many missing portions. As described above, 650°C to 750°C can be cited as ~~the~~a desired temperature range for carbonization which is required for a calcium to draw out as many functional groups as possible from the walls of the micro pores in the carbonized material as described above.

**[0024]**

——~~In this invention, a raw material which comprises plant(s) is contacted with a solution including calcium ions, and after that, carbonized, and an acid solution contacts with this carbonized material. It is considered that when the above-described Ca~~When the above described calcium charcoal 31, for example, is immersed in an HCl solution H, for example [see Fig. 9(A)], calcium ions which have combined with functional groups on the surface of the walls of the micro pores in Ca charcoal 31 and the above described functional groups [see Fig. 9(B)] combine with chloride ions [see Fig. 9(C)], so that acid treated Ca charcoal 32 [see Fig. 9(D)] where chloride ions combine with these functional groups directly or via calcium ions is ~~gained~~produced.

**[0025]**

As ~~the~~an acid solution for use in this invention, acid solutions which do not cause any problems in the subsequent treatment of wastewater at the time of manufacture, such as HCl and H<sub>2</sub>SO<sub>4</sub>, can be cited. The concentration of the acid solution ~~is~~can be no lower than 0.01 mol/L, that is to say, in a range from 0.01 mol/L to 20 mol/L, and a range from 0.1 mol/L to 10 mol/L is preferable. A concentration of lower than 0.01 mol/L has a disadvantage, such that sufficient desirable effects cannot be gained. Here, though it is desirable for the acid solution to

include anions which can be ion exchanged with anions that are the object of adsorption, there is no such limitation in the case where anions which can be ion exchanged with anions that are the object of adsorption are included in the solution with which the material originating from plant(s) is contacted before carbonization.

**[0026]**

In addition, it is efficient to carry out this acid treatment through immersion in an acid solution, and it is preferable to do this under reduced pressure, that is, it is preferable to do this under pressure in a range from 1330 Pa to 13.3 Pa.

**[0027]**

~~——In addition, the~~The present inventors have found, ~~as a result of diligent research,~~ that in the case where a raw material which comprises plant(s) has been contacted with a solution including a metal chloride, for example, a solution including  $\text{CaCl}_2$ , in advance, so that  $\text{CaCl}_2$  is introduced into the material before this material is carbonized, and after that, this material into which  $\text{CaCl}_2$  has been introduced is carbonized, the carbonized material gained as a result of this has excellent anion absorbing performance.

**[0028]**

Thus, a manufacturing method for an anion adsorbing carbon material ~~according to Claim 4~~ is characterized in that a raw material which comprises plant(s) is contacted with a solution including a metal chloride, and after that, carbonized, and the above described metal chloride is contained within this carbonized material. Chloride ions of the metal chloride that is contained within the carbonized material exhibit anion exchanging ability, and therefore, the carbonized material functions as an anion adsorbing carbon material. Here, as the method for contacting the solution that includes a metal chloride with the above described material originating from plant(s), though dripping, application, spraying, atomization and the like of the above described solution are possible, immersion of the above described material in the above described solution is most efficient.

**[0029]**

In accordance with the above described manufacturing method for an anion adsorbing carbon material, when the above described material originating from plant(s) is immersed in a solution including  $\text{CaCl}_2$  as a metal chloride, and thus, a process for introducing calcium ions and chloride ions into the material is carried out, and after that, this material into



which  $\text{CaCl}_2$  has been introduced is carbonized, excellent anion adsorbing ability can be recognized in the gained charcoal into which  $\text{CaCl}_2$  has been introduced.

**[0030]**

That is to say, as shown in Fig. 14(A), when ligneous chips 2, for example, which is a material, are immersed in a  $\text{CaCl}_2$  solution M so that they make contact with  $\text{CaCl}_2$  solution M, calcium ions and chloride ions in  $\text{CaCl}_2$  solution M are introduced into ligneous chips 2, so that, as shown in Fig. 14(C), chips 35 into which  $\text{CaCl}_2$  has been introduced are gained. This is because, as shown in Fig. 14(B),  $\text{CaCl}_2$  solution M soaks into the tissue, in particular, the conductive tissue, in ligneous chips 2. Here, as the concentration of the above described  $\text{CaCl}_2$  solution M that is used for pre-processing (contact processing) on the material, 0.1 weight % to 50 weight % of  $\text{CaCl}_2$  is preferable, and 1 weight % to 20 weight % is more preferable, in terms of cost. In the case where the concentration is lower than 0.1 weight %, high anion adsorbing ability is not gained, while in the case where the concentration exceeds 50 weight %, the anion adsorbing ability does not increase.

**[0031]**

Next, when the above described chips 35 into which  $\text{CaCl}_2$  has been introduced are carbonized, as shown in Fig. 15(A), a carbon material 37 is gained, as shown in Fig. 15(C). During this process of carbonization, organic matter in chips 35 into which  $\text{CaCl}_2$  has been introduced decomposes due to heat, and at the same time, chloride ions and calcium ions deposit on the surface of the walls of the micro pores in chips 35 into which  $\text{CaCl}_2$  has been introduced. At this time, as shown in Fig. 15(B), chloride ions and calcium ions deposit on the surface of the walls of the micro pores in chips 35, into which  $\text{CaCl}_2$  has been introduced, in a fine and highly dispersed state, and draw out many functional groups from every corner in the walls of the micro pores. As a result, as shown in Fig. 15(C), it is considered that a state where chloride ions combine with a great number of functional groups which have been drawn to the surface of the walls of the micro pores directly or via metal ions (in this case, calcium ions) is gained.

~~—In addition, a manufacturing method for an anion adsorbing carbon material according to Claim 5 is characterized in that a raw material which comprises plant(s) with which a solution including a metal chloride have contacted is carbonized and the above described metal chloride is contained within this carbonized material. That is to say, in the case a raw material which comprises plant(s)~~

~~with which a solution including a metal chloride has contacted is prepared in advance, the same anion adsorbing carbon material as that in the invention according to Claim 4 can be gained, simply by carbonizing this material.~~

**[0032]**

Here, as the content of the above described metal chloride, it is desirable for 2% to 25% of the metal chloride which combines within the carbonized material to be contained as ash content ~~(Claim 6)~~. The metal compound which combines within the carbonized material is a metal chloride excluding metal chlorides which simply adhere to the inside of the carbonized material, that is to say, a metal chloride which combines within the carbonized material, and therefore, remains undissolved after being washed with water or an acid. In the case where the content is lower than 2%, the anion adsorbing ability becomes inferior, while, in the case where the content exceeds 25%, the anion absorbing ability tends not to increase.

**[0033]**

~~Furthermore, it is preferable for the above described carbonized material to be contacted with water and/or an acid in the invention according to any of Claims 4 to 6 (Claim 7).~~  
Here, ~~as the~~ As a method for contacting water and/or an acid with the above described carbonized material, though dripping, application, spraying, atomization or the like of water and/or acid is possible, immersion of the above described carbonized material in water and/or an acid is most efficient.

**[0034]**

~~Here, the~~ The reason why it is preferable to contact water and/or an acid with the above described carbonized material can be considered to be as follows. That is to say, when carbon material (CaCl<sub>2</sub> charcoal) 37 which has been ~~gained~~ produced as shown in Figs. 14 and 15 is immersed in (contacted with) an acid, for example, hydrochloric acid H or sulfuric acid, as shown in Fig. 16(A), extra crystal of a metal chloride which adheres to carbon material 37 is removed. In addition, in the case where hydrochloric acid H is used as the acid, new chloride ions which combine with the functional groups of the above described carbon material 37 are added, so that the state changes from that shown in Fig. 16(B) to that shown in Fig. 16(C), and as a result of this, the anion adsorbing ability of the manufactured anion adsorbing carbon material increases, which is preferable. Here, in the case where water contacts with the above described

carbonized material instead of an acid, such as hydrochloric acid H, extra crystal of a metal chloride adhering to carbon material 37 is removed, and the anionic adsorbing ability increases.

~~Here, as the material in the invention according to any of Claims 4 to 7, though any plant can be used, materials of one or more types from natural fibers and ligneous materials of which the carbonized material has micro pores are preferable, and any type of ligneous material, such as thinning, lumber, and waste wood, and natural fibers such as hemp can be cited as examples. In particular, it is preferable to use ligneous chips of a size of no greater than 50 mm gained by processing a conifer, such as Japanese cypress or cedar having high water absorbency as the above described material originating from plant(s). Furthermore, in addition to the above described ligneous chips, bamboo, sawdust, chaff, coconut palm, betel nut palm, jute, straw, agricultural waste, such as peels from mandarin oranges and apples and pulp from mandarin oranges and apples may be used. In addition, the portion of plants having conductive tissue (vessels, tracheids and sieve tubes) are particularly preferable.~~

~~Concretely,  $\text{CaCl}_2$  and  $\text{BaCl}_2$  can be cited as the above described metal chloride (Claim 8).~~  
**[0035]**

**Here,  $\text{CaCl}_2$  and  $\text{BaCl}_2$  can be cited as the above described metal chlorides.**

**[0036]**

~~In addition, in the invention according to any of the above described Claims 1 to 8, it~~  
is preferable for the temperature for carbonization of the above described material to be 400°C to 1000°C. This is because in the case where the temperature for the carbonization process is lower than 400°C, micro pores are not created, and the performance as a an adsorbing material becomes inferior, while in the case where the above described temperature exceeds 1000°C, adsorbing properties are not gained, due to excessive carbonization. Here, the temperature for the carbonization process is more preferably 500°C to 900°C, and most preferably approximately 600°C to 800°C.

~~—The anion adsorbing carbon material according to Claim 9 is characterized by being manufactured by the manufacturing method for an anion adsorbing carbon material according to any of Claims 1 to 8.~~

**[0037]**

In addition, the anion adsorbing carbon material of this invention may be gained by removing the adsorbed anions from the anion adsorbing carbon material ~~according to Claim 9~~ which has adsorbed anions and combining anions which can be ion exchanged with anions which are the next object of adsorption with the carbon material in place of the above described removed anions ~~(Claim 10)~~. Here, anions which can be adsorbed by the anion adsorbing carbon material of this invention are anions which can be an ion exchanged with anions that have combined in advance with the surface of the walls of the micro pores in the carbon material, and are naturally anions excluding the anions which have combined with functional groups on the surface of the walls of the micro pores in the above described carbon material directly or via metal ions.

**[0038]**

A manufacturing facilities for an anion adsorbing carbon material ~~according to Claim 44~~ is characterized by comprising a carbonization apparatus for carbonizing a raw material which comprises plant(s) and an apparatus for contacting a carbonized material which is produced by this carbonization apparatus with an acid solution.

**[0039]**

In this case, a carbonization furnace which allows for setting of the temperature for carbonization is used as the carbonization apparatus. In addition, any type of well-known container for an acid solution, such as an acid-resistant tank, can be used as the apparatus for contacting the carbonized material which is produced by this carbonization apparatus with an acid solution.

~~—In addition, a manufacturing facilities for an anion adsorbing carbon material according to Claim 12 is characterized by comprising an apparatus for contacting a raw material which comprises plant(s) with a solution including calcium ions, a carbonization apparatus for carbonizing the above~~

~~described material after it has been contacted with the solution, and an apparatus for contacting the carbonized material which has been produced by this carbonization apparatus with an acid solution.~~

**[0040]**

~~——In this case, any~~**Any** type of well-known container, such as a tank, can be used as the apparatus for contacting a raw material which comprises plant(s) with a solution including calcium ions. In addition, a carbonization furnace which allows for setting of the temperature for carbonization is used as the carbonization apparatus. In addition, any type of well-known container for an acid solution, such as an acid-resistant tank, can be used as the apparatus for contacting the carbonized material which is produced by this carbonization apparatus with an acid solution.

**[0041]**

As the method (apparatus) for contacting the solution including calcium ions with the above described material originating from plant(s), dripping, application, spraying, atomizing or the like of the solution including calcium ions is possible, and immersion of the above described material in the solution including calcium ions is most efficient. In addition, as the method (apparatus) for contacting the acid solution with the carbonized material, dripping, application, spraying, atomizing or the like of the acid solution is possible, and immersion of the carbonized material in the acid solution is most efficient.

~~——In accordance with the invention according to Claim 11, a raw material which comprises plant(s) is carbonized, and after that, this carbonized material is contacted with an acid solution, and thereby, anions which can be ion-exchanged with anions that are the object of absorption can combine with functional groups which have formed on the walls of micro-pores in the carbonized material originating from plant(s) directly or via calcium ions, and in addition, in accordance with the invention according to Claim 12, a raw material which comprises plant(s) which has contacted with a solution including calcium ions is carbonated, and after that, this carbonated material is contacted with an acid solution, and thereby, anions which can be ion-exchanged with anions that are the object of absorption can combine with functional groups which have been formed by being drawn out from the walls of the micro pores in the carbonized material directly or via calcium ions.~~

~~—— In a manufacturing facilities for an anion adsorbing carbon material according to Claim 11 or 12, the carbonization apparatus may allow for the formation of micro pores inside the carbonized material originating from plant(s), as well as the formation of a great number of functional groups on these walls of the micro pores, and the apparatus for contacting the carbonized material with an acid solution may allow for the combination of the above described functional groups with anions which can be ion exchanged with anions that are the object of absorption directly or via calcium ions (Claim 13).~~

~~—— The present inventors found, as a result of diligent research, that more functional groups of the carbonized material can be created by controlling the temperature and the time during the process of carbonization. That is to say, in the case where no calcium is introduced into the above described material, as in the invention according to Claim 11, the difference in the amount of created functional groups of the carbonized material is small, irrespectively of the temperature for heating at the time of carbonization. Meanwhile, the present inventors confirmed that in the case where calcium is introduced into the above described material in advance, as in the invention according to Claim 12, more functional groups can be formed in the case where the material is naturally cooled after the temperature for carbonization of approximately 650°C to 750°C has been maintained for, for example, one hour, in comparison with a case where the material is naturally cooled after the temperature for carbonization of approximately 600°C or approximately 800°C has been maintained for one hour.~~

~~—— Particularly when a calcium is introduced, in the carbonized material that has been carbonized at a temperature for carbonization of approximately 650°C to 750°C, as described above, a state where microscopic particles of a calcium compound half deposit on the surface of the walls of the micro pores in the above described carbonized material and uniformly disperse was observed through an electron microscope. Meanwhile, when the temperature for carbonization was approximately 600°C, a state where microscopic particles of a calcium compound have not sufficiently deposited on the surface of the walls of the micro pores as described above was observed. In addition, when the temperature for carbonization was approximately 800°C, though~~

deposition of microscopic particles of a calcium compound on the surface of the walls of the micro-pores as described above was observed, the state was such that there were many missing portions. As described above, approximately 650°C to 750°C can be cited as the temperature for carbonization which is required for calcium to draw out as many functional groups as possible from the surface of the walls of the micro-pores in the carbonized material, as described above.

— As the acid solution of this invention, acid solutions which do not cause any problems with treatment of wastewater at the time of manufacture, such as HCl and H<sub>2</sub>SO<sub>4</sub>, can be cited. The concentration of the acid solution is no lower than 0.01 mol/L, that is to say, in a range from 0.01 mol/L to 20 mol/L, and a range from 0.1 mol/L to 10 mol/L is preferable. A concentration of lower than 0.01 mol/L has a disadvantage, such that sufficient effects cannot be gained. Here, though it is desirable for the acid solution to include anions which can be ion-exchanged with anions that are the object of adsorption, there is no such limitation in the case where anions which can be ion-exchanged with anions that are the object of adsorption are included in the solution with which the material originating from plant(s) is contacted before carbonization.

— In the invention according to Claim 11, an acid solution, for example, an HCl solution, can contact with the walls of the micro-pores in the carbonized material which has been gained by carbonizing a raw material which comprises plant(s) using the carbonization apparatus, and thereby, anions, for example, chloride ions, which can be ion-exchanged with anions, for example, nitrate-nitrogen or nitrite-nitrogen, which is the object of absorption, can combine with the functional groups which formed on the surface of the walls of the micro-pores in the carbonized material originating from plant(s). This is considered to be because when the carbonized material is contacted with, for example, an HCl solution, chloride ions in the HCl solution combine with functional groups on the surface of the walls of the micro-pores in the carbonized material, so that acid-treated charcoal S where chloride ions combine with these functional groups are gained [see Fig. 1].

— Furthermore, in the invention according to Claim 12, an acid solution, for example, an HCl solution, contacts with the walls of the micro-pores of the carbonized material which has been gained by contacting a raw material which comprises plant(s) with a solution including calcium ions,

and after that, carbonizing the material, and thereby, anions, for example, chloride ions, which can be ion-exchanged with anions, for example, nitrate nitrogen or nitrite nitrogen, which is the object of adsorption, can combine with functional groups that have been drawn out from the above-described walls of the micro-pores directly or via calcium ions. This is considered to be because when the above-described Ca charcoal 31, for example, is immersed in an HCl solution H, for example [see Fig. 9(A)], calcium ions which have combined with functional groups on the surface of the walls of the micro-pores in Ca charcoal 31 and the above-described functional groups [see Fig. 9(B)] combine with chloride ions [see Fig. 9(C)], so that acid-treated Ca charcoal 32 [see Fig. 9(D)] where chloride ions combine with these functional groups directly or via calcium ions is gained.

—— In addition, it is efficient to carry out this acid treatment through immersion in an acid solution, and it is preferable to do this under reduced pressure, that is, it is preferable to do this under pressure in a range from 1330 Pa to 13.3 Pa.

—— The manufacturing facilities for an anion-adsorbing carbon material according to Claim 14 is characterized by comprising a carbonization apparatus for carbonizing a raw material which comprises plant(s) which has contacted with a solution including a metal chloride. In this case, a carbonization furnace for allowing for the setting of the temperature for carbonization is used as the carbonization apparatus.

—— The manufacturing facilities for an anion-adsorbing carbon material according to Claim 15 is characterized by comprising an apparatus for contacting a raw material which comprises plant(s) with a solution including a metal chloride and a carbonization apparatus for carbonizing the above-described material after it has contacted with the solution. In this case, a carbonization furnace for allowing for the setting of the temperature for carbonization is used as the carbonization apparatus. In addition, as the apparatus for contacting a solution including a metal chloride with the above-described material originating from plant(s), though an apparatus for dripping the above-described solution, an apparatus for applying the above-described solution, an apparatus for spraying the above-described solution, an apparatus for atomizing the above-described solution and the like are



~~possible, an immersion apparatus for immersing the above-described material in the above-described solution is most efficient.~~

~~—— In the case where a solution including a metal chloride contacts with the above-described material in advance, as shown in Claim 14, no means for contacting a material with a solution including a metal chloride is required in the manufacturing facilities for an anion adsorbing carbon material, while in the case where a manufacturing facilities for an anion adsorbing carbon material has an apparatus for contacting a material with a solution including a metal chloride as in Claim 15, a material originating from any type of a plant can be used.~~

~~—— In addition, the metal chloride which combines within the above-described carbonized material is a metal chloride excluding metal chlorides which simply adhere to the inside of the carbonized material, that is to say, a metal chloride which combines within the carbonized material, and therefore, remains undissolved after being washed with water or an acid. Thus, in the case where the content of the metal chloride is lower than 2%, the anion adsorbing ability becomes inferior, while, in the case where the content exceeds 25%, the anion adsorbing ability tends not to increase. Accordingly, it is desirable for 2% to 25% of the metal chloride which combines within the carbonized material to be contained as an ash component.~~

~~—— A carbonization apparatus according to Claim 14 or 15 may carbonize a raw material which comprises plant(s), form micro pores inside, and draw out a great number of functional groups to the surface of the walls of these micro pores, and combine anions which can be ion-exchanged with anions that are the object of adsorption directly or via metal ions (Claim 16). Here, anions which can be adsorbed by the anion adsorbing carbon material are anions which can be ion-exchanged with anions that have combined in advance with the surface of the walls of the micro pores in the carbon material, and are naturally anions excluding the anions included in the metal chloride which has combined with functional groups on the surface of the walls of the micro pores in the above-described carbon material directly or via metal ions.~~

~~—— An apparatus for contacting a carbonized material which has been created by the above-described carbonization apparatus with water and/or an acid solution, to remove extra crystal of the~~

metal chloride which adheres to the carbonized material, and to increase anion adsorbing ability, may be provided (Claim 17). Here, as the method for contacting the above-described carbonized material with water and/or an acid, though dripping, application, spraying, atomization or the like of water and/or acid is possible, immersion of the above-described carbonized material in water and/or an acid is most efficient.

—— The configuration may be provided with a drying area for an intermediate body for gaining an anion adsorbing carbon material so that the above-described intermediate body is dried in this drying area using heat discharged from the carbonization apparatus (Claim 18).

—— In the invention according to any of Claims 11 to 18, the temperature for carbonization in the above-described carbonization apparatus may be 400°C to 1000°C. Here, this temperature for carbonization is preferably 500°C to 900°C, and is more preferably 650°C to 750°C.

—— In the case where  $\text{CaCl}_2$  is used as the metal chloride, it was found through observation through an electron microscope that more functional groups can be formed and microscopic particles of the metal chloride half deposit on the surface of the walls of the micro pores in the carbonized material and uniformly dispersed, particularly when the material is naturally cooled after the carbonization apparatus has maintained a temperature for carbonization of approximately 650°C to 750°C for one hour.

#### [0042]

#### Effects of the Invention

—— In the invention according to any of Claims 1 to 3, a raw material which comprises plant(s) is contacted with a solution including calcium ions, and after, that, carbonized, and subsequently, was contacted with an acid solution, a raw material which comprises plant(s) which has contacted with a solution including calcium ions is carbonized, and this carbonized material is contacted with an acid solution, or a carbonized material gained by carbonizing a raw material which comprises plant(s) which has contacted with a solution including calcium ions is contacted with an acid solution, and therefore, an anion adsorbing carbon material having anion adsorbing properties equal or superior to those of an anion exchange resin can be gained by setting an appropriate temperature for carbonization. In addition, an anion adsorbing carbon material

manufactured in accordance with the above described manufacturing method for an anion adsorbing carbon material has a material originating from plant(s) as a main body and is environmentally friendly.

~~—— In the invention according to any of Claims 4 to 8, an anion adsorbing carbon material having anion adsorbing properties which are equal or superior to those of an anion exchange resin can be gained. Furthermore, this anion adsorbing carbon material has a raw material which comprises plant(s) as a main body and is environmentally friendly.~~

[0043]

~~—— In addition, in the invention according to Claim 9, an~~An ~~anion adsorbing carbon material which can be repeatedly restored for use can be gained.—— In addition as described in Claim 10, the~~ The ~~adsorbed anions are removed from the above described anion adsorbing carbon material, and anions which can be ion exchanged with anions that are the next object of adsorption are combined with the above described anion adsorbing carbon material in place of the above described removed anions, and thereby, the above described anion adsorbing carbon material can be repeatedly restored for use.~~

~~—— In the invention according to Claim 11, a carbonization apparatus for carbonizing a raw material which comprises plant(s) and an apparatus for contacting a carbonized material which has been created in this carbonization apparatus with an acid solution are provided, and therefore, an acid solution can contact with the walls of the micro pores in the carbonized material, and thus, anions which can be ion exchanged with anions that are the object of adsorption can be combined with the functional groups which have formed on the walls of the above described micro pores.~~

~~—— In addition, in the invention according to Claim 12, an apparatus for contacting a raw material which comprises plant(s) with a solution including calcium ions, a carbonization apparatus for carbonizing the above described material after it has been contacted with the solution, and an apparatus for contacting a carbonized material which has been created by this carbonization apparatus with an acid solution are provided, and therefore, an acid solution can contact with the walls of the micro pores of a carbonized material, and anions which can be ion exchanged with anions that are the object of adsorption can be combined with the functional groups which have~~

~~been drawn out from and formed on the walls of the above described micro pores directly or via calcium ions.~~

**[0044]**

Therefore, an anion adsorbing carbon material having anion adsorbing ability can be gained without any problems in the treatment of wastewater with Fe, unlike in the case where a raw material which comprises plant(s) is immersed in a solution of iron chloride after being carbonized.

**[0045]**

In addition, in this invention, an anion adsorbing carbon material having anion adsorbing properties which are equal or superior to those of an anion exchange resin can be gained by setting an appropriate temperature for carbonization when a raw material which comprises plant(s) is contacted with a solution including calcium ions, and after that, carbonized.

**[0046]**

~~—— In the invention according to Claim 13, a~~ raw material which comprises plant(s) is carbonized, and thereby, micro pores are formed inside, and a great number of functional groups are formed on the walls of these micro pores, and therefore, these functional groups can combine with anions which can be ion exchanged with anions that are the object of adsorption directly or via calcium ions, so that the anion adsorption ability of the carbonized material can be efficiently increased.

**[0047]**

In an anion adsorbing carbon material formed by a manufacturing facilities for an anion adsorbing carbon material ~~of the invention according to Claim 14 or 15,~~ chloride ions of the metal chloride which is contained within the carbonized material exhibit anion exchanging ability, and therefore, the carbonized material functions as an anion adsorbing carbon material.

**[0048]**

In the case where the above described carbonization apparatus carbonizes a raw material which comprises plant(s) so that micro pores are formed inside and a great number of functional groups are drawn out to the surface of the walls of these micro pores, and at the same time, anions (for example, Cl-) which can be ion exchanged with anions (for example, NO<sub>3</sub>-) that are the object of adsorption are combined with these functional groups directly or via metal ions-

(Claim 16), the anion adsorption ability can be efficiently increased by carbonizing a raw material which comprises plant(s) which has contacted with a metal chloride.

**[0049]**

In the case where an apparatus for removing extra crystal of a metal chloride that adheres to the carbonized material so that the anion adsorbing ability increases by contacting a carbonized material which has been created in the above described carbonization apparatus with water and/or an acid solution is provided (Claim 17), the anion adsorption ability of the anion adsorbing carbon material can further be increased, which is preferable.

**[0050]**

In the case where the configuration is provided with a drying area for drying an intermediate body for gaining an anion adsorbing carbon material, so that the above described intermediate body is dried by using the heat that is discharged from the carbonization apparatus in this drying area (Claim 18), the time for heating which is required for carbonizing this intermediate body can be shortened. In addition, in the case where an intermediate body made of a carbonized material is contacted with water and/or an acid solution, this intermediate body is dried, and thereby, a lightweight anion adsorbing carbon material which is easy to handle can be gained. Here, an intermediate body is dried using discharged heat in the drying area, and therefore, energy can be used efficiently.

**BRIEF DESCRIPTION OF THE DRAWINGS**

**[0051]**

**The objects and features of the present invention, which are believed to be novel, are set forth with particularity in the appended claims. The present invention, both as to its organization and manner of operation, together with further objects and advantages, may best be understood by reference to the following description, taken in connection with the accompanying drawings.**

**[0052]**

~~Brief Description of the Drawings~~

Fig. 1 is a diagram showing the configuration of the entirety of the first embodiment;

**[0053]**

Fig. 2 is a diagram illustrating ~~the entirety of the manufacturing process~~ **steps** according to the above described embodiment-;

**[0054]**

Fig. 3 is a diagram showing ~~the a~~ configuration of ~~the entirety of the a~~ second embodiment.

**[0055]**

Fig. 4 is a diagram illustrating ~~the entirety of the manufacturing process~~ **steps** according to the second embodiment-;

**[0056]**

Fig. 5 is a graph respectively showing the amount of nitrate nitrogen and nitrite nitrogen adsorbed by anion adsorbing carbon materials which ~~are gained~~ **were produced** in the first and second embodiments during **an** adsorption testing-;

**[0057]**

Fig. 6 is a graph respectively showing the amount of fluoride ions adsorbed by anion adsorbing carbon materials which ~~are gained~~ **were produced** in the first and second embodiments during **the** adsorption testing-;

**[0058]**

Fig. 7 is a diagram showing the steps in contacting a raw material which comprises plant(s) with a solution including calcium ions in the second embodiment-;

**[0059]**

Fig. 8 is a diagram showing the steps in carbonizing the above described material after it has been contacted with the solution in the second embodiment-;

**[0060]**

Fig. 9 is a diagram showing the steps in contacting a carbonized material which has been created by the carbonization apparatus with an acid solution in the second embodiment-;

**[0061]**

Fig. 10 is a diagram showing ~~the a~~ mechanism for nitrate ion adsorption in an anion adsorbing carbon material gained in the second embodiment-;

**[0062]**

Fig. 11 is a diagram schematically showing the configuration of a-facilities for manufacturing an anion adsorbing carbon material according to the third embodiment of this invention-;

**[0063]**

Fig. 12(A) is a diagram showing an example of an anion adsorbing carbon material, and Fig. 12(B) is a diagram showing an example of the above described anion adsorbing carbon material after processing-;

**[0064]**

Fig. 13 is a diagram showing an example of a-process steps for manufacturing a carbon material as that described above using the above described manufacturing facilities-;

**[0065]**

Figs. 14(A) to 14(C) are diagrams showing a detail in Step S2 in Fig. ~~43-13~~;

**[0066]**

Figs. 15(A) to 15(C) are diagrams showing a detail in Step S4 in Fig. ~~43-13~~;

**[0067]**

Figs. 16(A) to 16(C) are diagrams showing a detail in Step S5 in Fig. ~~43-13~~;

**[0068]**

Figs. 17(A) to 17(D) are diagrams showing a detail during adsorption of nitrate ions in the above described embodiment, and Fig. 17(E) is a diagram showing the carbon material after restoration-;

**[0069]**

Fig. 18 is a graph showing the results of comparison of the adsorbed amount of nitrate nitrogen/nitrite nitrogen between the above described carbon material and a material for comparison-;

**[0070]**

Fig. 19 is a graph respectively showing the amount of nitrate nitrogen adsorbed by a carbon material which has been prepared by changing the concentration of a  $\text{CaCl}_2$  solution in Step S2 and by a carbon material gained through HCl treatment-; and

**[0071]**

Fig. 20 is a graph showing the results of comparison of the adsorbed amount of fluoride ions between the above described carbon material and material for comparison.

### **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

**[0072]**

**Reference will now be made in detail to the preferred embodiments of the invention which set forth the best modes contemplated to carry out the invention, examples of which are illustrated in the accompanying drawings. While the invention will be described in conjunction with the preferred embodiments, it will be understood that they are not intended to limit the invention to these embodiments. On the contrary, the invention is intended to cover alternatives, modifications and equivalents, which may be included within the spirit and scope of the invention as defined by the appended claims. Furthermore, in the following detailed description of the present invention, numerous specific details are set forth in order to provide a thorough understanding of the present invention. However, it will be obvious to one of ordinary skill in the art that the present invention may be practiced without these specific details. In other instances, well known methods, procedures, components, and circuits have not been described in detail as not to unnecessarily obscure aspects of the present invention.**

**[0073]**

Explanation of **Drawing** Symbols

- 1 carbonization apparatus
- 2 raw material which comprises plant(s)
- 3 apparatus for contacting carbonized material with acid solution
- 10 apparatus for contacting material with solution including metal chloride
- 12, 24 drying area
- 22 apparatus for increasing anion adsorbing ability
- A, 31, 36 carbonized material (intermediate body)
- C solution including calcium ions
- H acid solution
- M solution including metal chloride



S, 30, 32, 35, 37

intermediate bodies

[0074]

#### Best Mode for Carrying Out the Invention

~~—In the following, the embodiments of this invention are described in reference to the drawings.—~~

~~Here, this invention is not limited to these embodiments.~~

Figs. 1 and 2 show ~~the~~a first embodiment of ~~this~~the invention.

[0075]

In Figs. 1 and 2, 1 indicates a carbonization furnace (an example of a carbonization apparatus for carbonizing a raw material which comprises plant(s)) for carbonizing a ligneous material (an example of a raw material which comprises plant(s)) 2 of plant(s), for example, natural fibers, including hemp, or lumber, without activating the material. Ligneous chips, for example, ~~are~~can be used as the above described material 2. These ligneous chips are gained by processing a conifer, such as Japanese cypress or cedar having high water absorbency and can have a size of no greater than, for example, 10 mm.

[0076]

3 indicates facilities for acid treatment such as a tank which contact an acid solution with a carbonized material that has been created by carbonization apparatus 1, and has mixing blades 5 inside a container 4 for containing an acid solution H, for example, HCl and H<sub>2</sub>SO<sub>4</sub>. The concentration of this acid solution is, for example, 5 mol/L. Apparatus for acid treatment 3 treats charcoal A in chip form that has been gained in carbonization furnace 1 with acid. In addition, (1) acid treated charcoal (an example of an intermediate body) S which can be used immediately after acid treatment is used as it is. In addition, (2) the above described charcoal S may be neutralized with alkali after acid treatment if necessary, and in this case, (3) the neutralized acid treated charcoal S may be washed with water if necessary.

[0077]

6 indicates a drier for drying acid treated charcoal S after acid treatment or acid treated charcoal S after acid treatment, neutralization and washing with water using the heat discharged from the carbonization furnace. Here, drying may be omitted if the charcoal is used in a moist state. 6a (see Fig. 2) indicates a processing portion for processing the dried acid treated charcoal S. 7 indicates a product in pellet form which has been processed from the above

described dried acid treated charcoal S, and 8 indicates a product which has been formed by crushing dried acid treated charcoal S. Here, the products are processed in different ways, depending on the application. In addition, another product, where dried acid treated charcoal S is stuck to an unwoven cloth, for example, can be cited, in addition to products 7 and 8.

**[0078]**

Figs. 3 and 4 show ~~the~~a second embodiment of ~~this~~the invention.

**[0079]**

In Figs. 3 and 4, acid treated Ca charcoal 32, which is an example of an anion adsorbing carbon material is gained by drying ligneous material (an example of a raw material which comprises plant(s)) 2 of plant(s), for example, natural fibers, including hemp or lumber, using dryer 12 after immersion in a solution including calcium ions (for example, lime water C) which is prepared in a Ca introducing calcification apparatus (an example of an apparatus for contacting a raw material which comprises plant(s) with a solution including calcium ions) 9, ~~and subsequently~~2. Subsequently, carbonizing the material in a carbonization furnace (an example of a carbonization apparatus) 1 without activating the material, and after that, immersing the material in an acid solution H, for example, HCl or H<sub>2</sub>SO<sub>4</sub>, using an apparatus for acid treatment 3 for contacting the carbonized material which has been created by carbonization apparatus 1 with an acid solution, and furthermore, drying the material using a dryer 6 and processing the material in a processing portion 6a.

**[0080]**

In this embodiment, ligneous chips are used as the above described material originating from plant(s) (hereinafter, simply referred to as material) 2. These ligneous chips are gained by processing a conifer, such as Japanese cypress or cedar having high water absorbency and ~~have~~having a size of no greater than, for example, 10 mm.

**[0081]**

The above described Ca introducing apparatus 9 is an apparatus for introducing Ca into ligneous chips 2, and is provided with a container 10 which contains a solution including calcium ions in which ligneous chips 2 are immersed. In this embodiment, ligneous chips 2 are immersed in the lime water C, and ligneous chips 2 are immersed in the lime water C of a predetermined concentration (for example, 5 weight %), and after that, taken out from container 10, and thereby, chips into which Ca has been introduced (an example of an intermediate body) 30 can be gained.

In this case, it is preferable to drive mixing blades 10a which are provided inside container 10 while the ligneous chips are immersed, in order for the solution to sufficiently soak into ligneous chips 2, or for calcium ions to sufficiently react with a component of ligneous chips 2.

**[0082]**

The gained chips 30 into which Ca has been introduced are dried using the above described dryer 12. In this embodiment, dryer 12 dries chips 30 into which Ca has been introduced using heat discharged from the carbonization furnace. Here, the efficiency in processing improves when milk of lime is used. In addition, a calcium chloride solution or a calcium acetate solution can be used instead of lime water C or milk of lime.

**[0083]**

The dried chips 30 into which Ca has been introduced are carbonized in carbonization furnace 1, so that Ca charcoal (an example of an intermediate body made of a carbonized material) 31 in chip form is gained. As for the conditions for carbonization in this embodiment, the temperature for carbonization is 650°C to 750°C for a period of one hour.

**[0084]**

The above described apparatus for acid treatment 3 is provided with a container 4 which contains an acid solution H, for example, HCl or H<sub>2</sub>SO<sub>4</sub>, and mixing blades 5 are provided inside this container 4. The concentration of this acid solution H is, for example, 5 mol/L. In the above described apparatus for acid treatment 3, Ca charcoal 31 in chip form that has been gained in carbonization furnace 1 is treated with acid, so that acid treated Ca charcoal 32 is gained. In addition, it is preferable to drive mixing blades 5 which are provided inside container 4, so that dissolving of calcium carbonate (CaCO<sub>3</sub>) on the surface of Ca charcoal 31 in the acid is accelerated and chloride ions and calcium ions sufficiently react with functional groups on the surface of the above described Ca charcoal 31. The gained acid treated Ca charcoal (an example of an intermediate body made of a carbonized material) 32 is dried using the above described drier 6. In this embodiment, dryer 6 dries acid treated Ca charcoal 32 using heat being discharged from the carbonization furnace to lower the cost of the processing.

**[0085]**

In addition, (1) acid treated Ca charcoal 32 which can be used immediately after acid treatment step and the drying step is processed directly into a final product as an anion

adsorbing material. In addition, (2) acid treated Ca charcoal 32 may be further neutralized with alkali after treatment with acid if necessary, and in this case, (3) the neutralized acid treated Ca charcoal may be washed with water if necessary. Here, drying may be omitted in the case where the product is to be used in a moist state.

**[0086]**

7' indicates a product in pellet form which is gained by processing acid treated Ca charcoal 32, and 8' is a product which is formed by crushing acid treated Ca charcoal 32. Here, the products are processed differently, as shown below, depending on the application. In addition, another product where acid treated Ca charcoal 32 is stuck to an unwoven cloth, for example, can be ~~ited~~created, in addition to products 7' and 8'. Here, in some cases, chips 30 into which Ca has been introduced and Ca charcoal 31 are prepared in separate factories, and in such cases, manufacturing of acid treated Ca charcoal 32 may start in the middle of the process in each of the above described embodiments. In addition, acid treated Ca charcoal 32 can be used as it is, without processing. <Nitrate Nitrogen and Nitrite Nitrogen Adsorbing Test>

**[0087]**

[Testing Method]

Five containers having 50 ml of nitrate solution and nitrite solution of ~~the~~a concentration of 50 mg/L (50 ppm), respectively, were prepared (standard liquid), and five types of the following samples were put into the corresponding containers for each standard liquid, and the containers were shaken for ten hours under the conditions of, for example, 200 rpm at 20°C, and after that the concentration of nitrate nitrogen and the concentration of nitrite nitrogen in the above described nitrate solution and nitrite solution were respectively measured and the amount of adsorption was calculated:

**[0088]**

(1) 200 mg of charcoal, which was gained by carbonizing ligneous chips 2 at 700°C (hereinafter simply referred to as charcoal) ~~and~~was used as a comparative example,

**[0089]**

(2) 200 mg of iron chloride charcoal, which was ~~gained~~produced by immersing charcoal which had been gained by carbonizing ligneous chips 2 at 700°C in 1 mol/L of an FeCl<sub>3</sub> solution and after that washing the charcoal with water, ~~and~~was used as a comparative example,

**[0090]**

(3) 200 mg of acid treated charcoal, which was ~~gained~~**prepared** by immersing charcoal which had been ~~gained~~**produced** by carbonizing ligneous chips 2 at 700°C in 5 mol/L of an HCl solution and after that washing the charcoal with water,

**[0091]**

(4) 200 mg of acid treated Ca charcoal 32 (anion adsorbing carbon material), which was gained by immersing charcoal which had been gained by immersing ligneous chips 2 in 5 weight % of lime water, and after that, carbonizing the chips at 700°C in 5 mol/L of an HCl solution, and

**[0092]**

(5) 200 mg of an anion exchange resin, which was used as a comparative example.

**[0093]**

**[Results]**

Fig. 5 shows ~~thea~~ comparison in the adsorbing abilities of nitrate nitrogen and nitride nitrogen among the above described respective samples. The charcoal of (1) which was carbonized at 700°C barely adsorbed nitrate nitrogen or nitrite nitrogen, while the iron chloride charcoal of (2) adsorbed 2.75 mg/g and 2.35 mg/g of nitrate nitrogen and nitrite nitrogen, respectively. In addition, acid treated charcoal S of (3) adsorbed 2.50 mg/g and 2.20 mg/g of nitrate nitrogen and nitrite nitrogen, respectively. The anion exchange resin of (5) adsorbed 10.80 mg/g and 10.00 mg/g of nitrate nitrogen and nitrite nitrogen, respectively.

**[0094]**

Meanwhile acid treated Ca charcoal 32 of (4), which was gained by immersing ligneous chips 2 in lime water C, and after that, carbonizing the chips, and subsequently immersing the chips in an HCl solution, adsorbed 10.75 mg/g and 9.80 mg/g of nitrate nitrogen and nitrite nitrogen, respectively, and exhibited ~~thean~~ adsorption ability which was equal to or greater than that of the anion exchange resin of (5).

**[0095]**

In addition, the mechanism for the above described acid treated Ca charcoal 32 to adsorb nitrate ions is considered as follows. As shown in Fig. 10(A), when acid treated Ca charcoal 32 (anion adsorbing carbon material) is immersed in a nitrate solution L, for example,

nitrate ions in nitrate solution L are exchanged with chloride ions [see Fig. 10(B)] which have combined with functional groups on the surface of the walls of the micro pores in ~~the~~ acid treated Ca charcoal 32 directly or via calcium ions [see Fig. 10(C)], and thus, the nitrate ions adsorbed by acid treated Ca charcoal 32 [see Fig. 10(D)]. Fig. 10(E) shows a change in acid treated Ca charcoal 32 shown in Fig. 10(D) when this is immersed in a KCl (or NaCl) solution. That is to say, the acid treated Ca charcoal 32 which has adsorbed nitrate ions can repeatedly be restored by exchanging nitrate ions with chloride ions in the KCl (or NaCl) solution. ~~In the following,~~ this ~~This~~ restoration test is described ~~as follows:~~

#### [0100]

<Restoration Test>

[Testing Method]

Samples of acid treated charcoal S and acid treated Ca charcoal 32 after the above described nitrate nitrogen adsorbing test had been carried out, were washed with 1 mol/L of a KCl (or NaCl) solution, and furthermore, it was washed with water. Subsequently, the standard liquid was exchanged and 50 ml (milliliter) of a nitrate solution of which the concentration of nitrate nitrogen was 50 mg/L was prepared as a standard liquid, and the first restoration test was carried out on the above described 200 mg of the samples which were washed with water. That is to say, the above described samples were put into a nitrate solution and the containers were shaken for ten hours under the conditions of, for example, 200 rpm at 20°C, and after that, the concentration of nitrate nitrogen in the above described nitrate solution was measured and the amount of adsorption was calculated, and in this manner, the first restoration test was carried out on the above described samples.

#### [0096]

Next, the above described samples which were used in the first restoration test were washed with a KCl (or NaCl) solution of 1 mol/L, and furthermore, it was washed with water. Subsequently, the standard liquid was exchanged and 50 ml (milliliter) of a nitrate solution of which the concentration of nitrate nitrogen was 50 mg/L was prepared and a restoration test was carried out on 200 ml of the above described samples which had been washed with water as described above. That is to say, the above described samples were put into 50 ml (milliliter) of a nitrate solution and the containers were shaken for ten hours under the conditions of, for

example, 200 rpm at 20°C, and after that, the concentration of nitrate nitrogen in the above described nitrate solution was measured and the amount of adsorption was calculated, and in this manner, the second restoration test was carried out on the above described samples. This process was repeated two additional times.

**[0097]**

**[Results]**

Amount of nitrate nitrogen adsorbed by acid treated charcoal S

Initial time	2.5 mg/g
First restoration time	2.5 mg/g
Second restoration time	2.4 mg/g
Third restoration time	2.5 mg/g

Amount of nitrate nitrogen adsorbed by acid treated Ca charcoal 32

Initial time	10.8 mg/g
First restoration time	10.6 mg/g
Second restoration time	10.9 mg/g
Third restoration time	10.7 mg/g

**[0098]**

It can be seen from the above that the above described acid treated charcoal S and acid treated Ca charcoal 32 after use can be washed with a dense KCl (or NaCl) solution, respectively, and furthermore, ~~it was washed with water, and thereby, can be restored. That is to say~~**Thus**, it was found that acid treated charcoal S and acid treated Ca charcoal (anion adsorbing carbon material) 32 which had adsorbed nitrate nitrogen (anions) in the nitrate nitrogen adsorbing test were respectively washed with a KCl (or NaCl) solution, and furthermore, ~~it was washed with water, and thereby, nitrate nitrogen (anions) which had been adsorbed in the nitrate nitrogen adsorbing test was~~**were** removed and Cl<sup>-</sup> was combined instead of the removed nitrate nitrogen (anions), and thus, acid treated charcoal S and acid treated Ca charcoal 32 (anion adsorbing charcoal material) were respectively restored. That is to say, it was confirmed that acid treated charcoal S and acid treated Ca charcoal 32 (anion adsorbing carbon material) ~~are~~**can be** respectively washed with a KCl (or NaCl) solution and then washed with water after each use, and thereby, they can be used a number of times. Here, in the case where nitrite nitrogen is

adsorbed and acid treated charcoal S and acid treated Ca charcoal are respectively used as an anion adsorbing carbon material, the restoration principle is the same.

**[0099]**

<Fluoride Ion Adsorbing Test>

[Testing Method]

50 ml (milliliter) of a solution of which the concentration of fluoride ions was 50 mg/L (standard liquid) was prepared in separate containers, and five types of the following samples were put into the corresponding containers for each standard liquid, and the containers were shaken for ten hours under the conditions of, for example, 200 rpm at 20°C, and after that, the concentration of fluoride ions in the above described solution were respectively measured and the amount of adsorption was calculated:

**[0100]**

(1) 100 mg of charcoal, which was gained by carbonizing ligneous chips 2 at 700°C (hereinafter simply referred to as charcoal) ~~and~~was used as a comparative example,

**[0101]**

(2) 100 mg of iron chloride charcoal, which was gained by immersing charcoal which had been gained by carbonizing ligneous chips 2 at 700°C in 1 mol/L of an FeCl<sub>3</sub> solution and after that washing the charcoal with water, ~~and~~was also used as a comparative example,

**[0102]**

(3) 100 mg of acid treated charcoal, which was gained by immersing charcoal which had been gained by carbonizing ligneous chips 2 at 700°C in 5 mol/L of an HCl solution and after that washing the charcoal with water,

**[0103]**

(4) 100 mg of an anion adsorbing carbon material (acid treated Ca charcoal 32), which was gained by immersing charcoal which had been gained by immersing ligneous chips 2 in 5 weight % of lime water, and after that, carbonizing the chips at 700°C in 5 mol/L of an HCl solution, and

**[0104]**

(5) 100 mg of an anion exchange resin, ~~which~~-was used as a comparative example.

[Results]



**[0105]**

Fig. 6 shows ~~the~~a comparison ~~in~~of the fluoride ion adsorbing ability among the above described respective samples.

**[0106]**

The charcoal of (1) carbonized at 700°C barely adsorbed chloride ions, while the ion chloride charcoal of (2) adsorbed 7.50 mg/g of fluoride ions. In addition, acid treated charcoal S of (3) adsorbed 5.00 mg/g of fluoride ions. The anion exchange resin of (5) adsorbed 8.50 mg/g of fluoride ions.

**[0107]**

Meanwhile, acid treated Ca charcoal 32 of (4) which had been gained by immersing ligneous chips 2 in lime water, and after that, carbonizing the chips, and subsequently, immersing the chips in an HCl solution adsorbed 19.00 mg/g of fluoride ions ~~and~~ exhibited an adsorption ability which greatly exceeded the anion exchange resin of (5).

**[0108]**

<Restoration Test>

[Testing Method]

Next, the samples of acid treated charcoal S and acid treated Ca charcoal 32 after the above described fluorine adsorbing test had been carried out, were washed with 1 mol/L of a hydrochloric acid (or sulfuric acid), and furthermore, ~~the~~the sample was washed with water. Subsequently, ~~the~~a standard liquid was exchanged and 50 ml (milliliter) of a solution of which the concentration of fluoride ions was 50 mg/L was prepared, and the first restoration test was carried out on the above described 200 mg of the samples which had been washed with water. That is to say, the above described samples were put into the above described solution and the containers were shaken for ten hours under the conditions of 200 rpm at 20°C, ~~and after that,~~ After shaking, the concentration of fluoride ions in the above described solution was measured and the amount of adsorption was calculated, and in this manner, ~~the~~a first restoration test was carried out on the above described samples. Next, the above described samples which had been used in the first restoration test were washed with 1 mol/L of a hydrochloric acid (or sulfuric acid), and furthermore, ~~it was~~ washed with water. Subsequently, the standard solution was exchanged and 50 ml (milliliter) of a solution of which the concentration of fluoride ions was 50

mg/L was prepared as described above, and a restoration test was carried out on 200 mg of the above described samples which had been washed with water as described above. That is to say, the above described samples were put into the containers of 50 ml (milliliter) of the above described solution, and the containers were shaken for ten hours under the conditions of, for example, 200 rpm at 20°C, and after that, the concentration of fluoride ions in the above described solution was measured and the amount of adsorption was calculated, and in this manner, the second restoration test was carried out on the above described samples. This process was repeated two additional times.

**[0109]**

**[Results]**

Amount of fluoride ions adsorbed by acid treated charcoal S was as follows:

Initial time	2.5 mg/g
First restoration time	2.5 mg/g
Second restoration time	2.4 mg/g
Third restoration time	2.5 mg/g

Amount of fluoride ions adsorbed by acid treated Ca charcoal 32

Initial time	18.7 mg/g
First restoration time	18.2 mg/g
Second restoration time	18.9 mg/g
Third restoration time	18.6 mg/g

**[0110]**

It can be seen from the above that ~~the above described~~ acid treated charcoal S and acid treated Ca charcoal 32 after use were respectively washed with a dense hydrochloric acid (or sulfuric acid), and furthermore, ~~it was washed with water, and thereby, were restored. That is to say, it~~ was found that the acid treated charcoal S and the acid treated Ca charcoal 32 (anion adsorbing carbon material) which had adsorbed fluoride ions (anions) in the fluorine adsorbing test were could be respectively washed with a hydrochloric acid (or sulfuric acid), and furthermore, ~~it was washed with water, and thereby,~~ the fluoride ions (anions) which had been adsorbed in the fluoride ion adsorbing test were removed and Cl<sup>-</sup> (or SO<sub>4</sub><sup>2-</sup>) was combined instead of the removed fluoride ions (anions), and thus, acid treated charcoal S and acid treated

Ca charcoal 32 (anion adsorbing carbon material) were restored, respectively. ~~That is to say~~**Thus**, it was confirmed that acid treated charcoal S and acid treated Ca charcoal 32 (anion adsorbing carbon material) which are once used can be washed with a hydrochloric acid (or sulfuric acid), and furthermore, ~~it was~~ washed with water, after each use, and thereby, can be used a number of times.

#### **[0111]**

Figs. 11 to 20 show ~~the~~**a** third embodiment of this invention. Fig. 11 schematically shows an example ~~of a~~**of** facilities for manufacturing an anion adsorbing carbon material (hereinafter referred to as carbon material) 37 according to the third embodiment of this invention, and in this figure, 2 indicates a plant material which is ligneous chips in this embodiment. These ligneous chips 2 are gained by processing a conifer, such as Japanese cypress or cedar having high water absorbency and have an appropriate size of no greater than, for example, 50 mm.

#### **[0112]**

In addition, the above described ligneous chips 2 are fed to a process tank 20 (apparatus for contacting a material with a solution including a metal chloride) which contain a metal chloride solution ( $\text{CaCl}_2$  solution in this embodiment) M having an appropriate concentration, and within this process tank 20, a process for introducing a metal chloride ( $\text{CaCl}_2$  in this embodiment) is carried out on ligneous chips 2 so that chips into which a metal chloride has been introduced (an example of an intermediate body) 35 are formed. Here, 20a indicates mixing blades which are provided within process tank 20 and are driven by a motor (not shown) so as to rotate, and thus, are used when stirring a liquid or the like within process tank 20. Here, it is preferable to add a slight amount of  $\text{Ca}(\text{OH})_2$  to the metal chloride solution in order to enhance the anion adsorbing ability.

#### **[0113]**

Chips 35 into which a metal chloride has been introduced and which have been gained as described above are dried using a drier 12, and after that, fed to a carbonization process furnace 1 (carbonization apparatus) where a carbonization process is carried out on the chips without activation. Here, the above described drier 12 is an example of a drying area for drying chips 35 into which a metal chloride has been introduced and which are an intermediate body for

gaining a carbon material 37, and is formed such that the heat discharged from carbonization process furnace 1 ~~is~~can be used for the above described drying.

**[0114]**

The main body 1a of the carbonization furnace which is heated by an appropriate heat source 21 is contained inside the above described carbonization process furnace 1. In addition, chips 35 into which a metal chloride has been introduced are supplied to the inside of the above described main body 1a of the carbonization furnace through an introduction portion 1b, and are heated at an appropriate temperature (described below) and for an appropriate period of time (described below) so as to be carbonized and converted to a carbonized material, and this carbonized material is discharged to the outside of the main body 1a of the carbonization furnace through a discharging portion 1c as carbon material 36, which is an example of an intermediate body.

**[0115]**

After that, the above described carbon material 36 is fed to a process tank 22 (apparatus for enhancing the anion adsorbing ability) which contains water or an HCl solution (hydrochloric acid) H, and a process for contacting (immersing) carbon material 36 with ~~(H)~~ water or a HCl solution H is carried out within this process tank 22. Here, 23 indicates mixing blades which are provided within process tank 22, and are driven by a motor (not shown) so as to rotate, and thus, are used when stirring a liquid or the like within process tank 22. In some cases, a process for contacting a material with water is carried out after a process for contacting the material with an acid, or they may be carried out in the opposite order.

**[0116]**

Next, carbon material (an example of an intermediate body) 37 which has been immersed in water or HCl solution H is fed to a drier 24 so as to be dried, and after that, are formed into grains (pellets) 7" having an appropriate diameter or further crushed into powder 8" which is finer than grains. Here, the above described drier 24 is an example of a drying area for drying carbon material 37 which is an intermediate body before being processed to pellets 7" or powder 8", and is formed so that the heat that is discharged from carbonization process furnace 1 is used for the above described drying.

**[0117]**

—Here, Fig. 12(A) shows the carbon material 37 which has been formed into chips having a length of approximately 10 mm and Fig. 12(B) shows an example of grains (pellets) 7" having an appropriate diameter which have been formed from the above described carbon material 37 in chip form.

**[0118]**

Next, an example of a procedure for ~~gaining~~**providing** carbon material 37 from plant material 2 using the facilities shown in Fig. 11 is described in detail in reference to Figs. 11 and 13. First, ligneous chips 2 which have been gained by processing a conifer, such as Japanese cypress or cedar having high water absorbency and have a size of no greater than, for example, 10 mm are prepared (Step S1).

**[0119]**

Next, the above described ligneous chips 2 are immersed in  $\text{CaCl}_2$  solution M which has been prepared so as to have 1 weight % to 20 weight % within process tank 20 for no less than, for example, three hours. It is preferable to rotate mixing blades 20a while these ligneous chips 2 are immersed. As a result,  $\text{CaCl}_2$  solution M soaks into ligneous chips 2, and thus, chips 35 into which a metal chloride has been introduced, that is, ligneous chips 2 into which calcium ions and chloride ions have been introduced are gained (Step S2).

**[0120]**

In addition, the above described chips 35 into which a metal chloride has been introduced are fed to drier 12 so as to be dried (Step S3).

**[0121]**

After that, the above described ligneous chips 2 are supplied to main body 1a of the carbonization furnace in carbonation process furnace 1, and is heated for approximately one hour in a temperature range ( $700^\circ\text{C}$  in this embodiment) from  $400^\circ\text{C}$  to  $1000^\circ\text{C}$  so that a carbonization process is carried out (Step S4). As a result, the **base intermediate** carbon material 37 is ~~gained~~**produced**.

**[0122]**

The above described carbon material 37 is supplied to a process tank 22 and is immersed and processed in HCl solution H that has been prepared so as to have 0.01 mol/L to 11

mol/L (for example, 5 mol/L) within process tank 22 (Step S5). In this case, it is preferable to rotate mixing blades 23, and thereby, extra crystal of the metal chloride ( $\text{CaCl}_2$ ) which remains within carbon material 37 can be removed and at the same time chloride ions can further be added, and thus, desired carbon material 37 is gained.

**[0123]**

In addition, carbon material 37 after the above described immersion process is dried in general using drier 24 (Step S6). In this case, carbon material 37 may be directly fed to drier 24, or a neutralization process such as immersion in an appropriate alkaline solution may be carried out, and additionally, the carbon material may be washed with water after the neutralization process. Here, in the case where carbon material 37 is used in a moist state, it may not be dried.

**[0124]**

In addition, though carbon material 37 in chip form after drying as described above can be used as is, the material has been formed into grains (pellets) 7" having an appropriate diameter or powder 8" which has finer particles using an appropriate processing machine in this embodiment (Step S7). In addition, it is possible to use the above described carbon material 37 in a state where, for example, it is stuck to an unwoven cloth in addition to being used as is.

**[0125]**

Here, the above described carbon material 37 is not necessarily manufactured by carrying out all the above described Steps S1 to S7 within the same factory. In the case where several steps from among the above described Steps S1 to S7 have been carried out during the manufacture in another factory, or the like, carbon material 37 may be manufactured by starting from a step in the middle.

**[0126]**

Here, this invention is not limited to any of the above described embodiments, and can be implemented by modifying in various manners.  $\text{BaCl}_2$ ,  $\text{MnCl}_2$ , and the like, for example, can be cited as the metal chloride, though  $\text{CaCl}_2$ , which ~~allows~~**is believed to provide** the anion adsorbing carbon material having the highest performance ~~to be gained~~, is used in the above described embodiments.

**[0127]**

In addition, in the above described embodiments, though a process for contacting carbon material 37 with HCl solution H is carried out within process tank 22, water may be used instead of HCl solution H. In this case, chloride ions are not added and extra ~~crystal~~crystals of a metal chloride which ~~remains~~remain within carbon material 37 is simply removed.

**[0128]**

Furthermore, in the above described embodiments, though carbon material 37 is fed to process tank 22 after it has been gained by carrying out a carbonization process on chips 35 into which a metal chloride has been introduced in the carbonization process furnace 1, it is not necessary to feed the carbon material to process tank 22. In this case, it becomes unnecessary to feed the above described carbon material 37 to drier 24, and therefore, the above described Steps S5 and S6 ~~are~~can be omitted from the manufacturing method for the carbon material 37. In addition, in this case the manufacturing method for carbon material 37 may be completed with Steps S1 to S4, or Step S7 may be carried out afterwards.

**[0129]**

Next, a test that was carried out in order to check the performance of the above described carbon material 37 ~~of in~~ adsorbing nitrate nitrogen and nitrite nitrogen is described. A test method and test results of the performance of adsorbing nitrate nitrogen and nitrite nitrogen are described in the following.

**[0130]**

First, two sets of samples (1) to (7), each of which was 200 mg and of which the total number of samples in one set was 7 were prepared as shown in the following. That is to say, two sets of the following samples, of which the total number in one set was 7, were prepared:

**[0131]**

(1) charcoal which was gained by heating and carbonizing ligneous chips 2 for 1 hour at 700°C,

**[0132]**

(2) iron chloride charcoal which was gained by heating and carbonizing ligneous chips 2 for 1 hour at 700°C, and after that immersing the chips in an FeCl<sub>3</sub> solution of 1 mol/L and then washing the chips with water,

**[0133]**

(3) an anion exchange resin,

**[0134]**

(4) BaCl<sub>2</sub> charcoal which was gained by immersing ligneous chips 2 in a BaCl<sub>2</sub> solution of 10 weight %, and after that, heating and carbonizing the chips for one hour at 700°C,

**[0135]**

(5) HCl processed BaCl<sub>2</sub> charcoal which was gained by immersing ligneous chips 2 in a BaCl<sub>2</sub> solution of 10 weight %, and after that, heating and carbonizing the chips for one hour at 700°C, and furthermore, immersing and processing the chips in an HCl solution of 5 mol/L,

**[0136]**

(6) CaCl<sub>2</sub> charcoal which was gained by immersing ligneous chips 2 in a CaCl<sub>2</sub> solution of 10 weight %, and after that, heating and carbonizing the chips for one hour at 700°C, and

**[0137]**

(7) HCl processed CaCl<sub>2</sub> charcoal which was gained by immersing ligneous chips 2 in a CaCl<sub>2</sub> solution of 10 weight %, and after that, heating and carbonizing the chips for one hour at 700°C, and furthermore, immersing and processing the chips in an HCl solution of 5 mol/L. Here, samples (4) to (7) corresponded to the above described carbon material 37 and samples (1) to (3) were provided for comparison with carbon material 37.

**[0138]**

Then samples in one set were individually put into 50 mL of nitrate nitrogen solution (first standard liquid) of which the concentration of nitrate nitrogen was 50 mg/L (50 ppm) and samples in the other set were individually put into 50 mL of nitrite nitrogen solution (second standard liquid) of which the concentration of nitrite nitrogen was 50 mg/L (50 ppm). After that, the containers of the solutions were shaken for ten hours under the conditions of 200 rpm at 20°C, and then, the concentration of nitrate nitrogen in the first standard liquid and the concentration of nitrite nitrogen in the second standard liquid were respectively measured, and



the amount of nitrate nitrogen and nitrite nitrogen which were adsorbed by each sample was calculated.

**[0139]**

Fig. 18 shows ~~the~~<sup>a</sup> comparison ~~results~~<sup>result</sup> in the nitrate nitrogen adsorbing ability and nitrite nitrogen adsorbing ability among the respective samples which were ~~gained~~<sup>produced</sup> in the above described test. Here, ~~this figure~~<sup>Figure 18</sup> shows the amount of nitrate nitrogen and nitrite nitrogen adsorbed by each sample is shown in pairs of bars in a graph, where the bars on the left show the amount of adsorbed nitrate nitrogen and the bars on the right show the amount of adsorbed nitrite nitrogen. It can be seen from the results shown in this graph that all the samples of the present invention have high nitrate nitrogen adsorbing ability and nitrite nitrogen adsorbing ability. Furthermore, the amount of adsorbed nitrate nitrogen and nitrite nitrogen is compared between  $\text{BaCl}_2$  charcoal of (4) and HCl processed  $\text{BaCl}_2$  charcoal of (5) and the amount of adsorbed nitrate nitrogen and nitrite nitrogen is compared between  $\text{CaCl}_2$  charcoal of (6) and HCl processed  $\text{CaCl}_2$  charcoal of (7), and thereby, it can be seen that it is better to carry out a process (HCl process) for immersing carbon material 37 in an HCl solution in order to enhance the nitrate nitrogen/nitrite nitrogen adsorbing ability of carbon material 37. However, carbon material 37 having a sufficiently high nitrate nitrogen/nitrite nitrogen adsorbing ability can still be gained without carrying out an HCl process, and in this case, carbon material 37 can be manufactured at a cost which is lower by the portion for carrying out a process for contacting the material with an HCl solution.

**[0140]**

Here, the above described carbon material 37 adsorbs, for example, nitrate ions, and this is considered to be because, as shown in Fig. 17(A), when carbon material ( $\text{CaCl}_2$  charcoal) 37 is immersed in a nitrate solution L, chloride ions which has been combined with functional groups on the surface of carbon material 37 directly or via calcium ions (see Fig. 17(B)) and nitrate ions in nitrate solution L are exchanged (see Fig. 17(C)) so that nitrate ions are adsorbed by carbon material 37 (see Fig. 17(D)).

**[0141]**

In addition, Fig. 17(E) shows a state of carbon material 37, which was initially in a state shown in Fig. 17(D) adsorbing nitrate ions, after being immersed in a chloride solution having a high concentration (for example, a metal chloride solution of KCl or NaCl, or HCl

solution H). That is to say, the nitrate ions which have been adsorbed by carbon material 37 are exchanged with chloride ions in chloride solution, and thereby, carbon material 37 is restored and becomes a state where it can adsorb anions such as nitrate ions. That is to say, carbon material 37 of this invention is not always limited to those which are newly gained in accordance with the above described manufacturing method, but may be those which are gained (that is to say, restored) by removing the adsorbed anions (for example, nitrate ions) from carbon material 37 which has been ~~gained~~**produced** in accordance with the above described manufacturing method and has adsorbed anions (nitrate ions) and combining anions (chloride ions in this embodiment) which can be ion exchanged with anions (for example, nitrate ions) of the next object of adsorption with the carbon material instead of the above described removed anion (nitrate ions). In addition, in the case where sulfuric acid is used instead of the above described chloride solution, nitrate ions are ion exchanged with sulfate ions instead of the above described chloride ions.

**[0142]**

Next, a test ~~which was~~ carried out in order to check how the concentration of metal chloride solution ( $\text{CaCl}_2$  solution) M into which ligneous chips 2 are immersed in the above described Step S2 effects the anion absorbing ability of carbon material 37 after the manufacture is described. In the above described test, carbon material 37 which was gained by immersing ligneous chips 2 in  $\text{CaCl}_2$  solution M, and after that carbonizing the chips by heating for one hour at  $700^\circ\text{C}$ , and then, washing the chips with water, was put into 50 mL of nitrate nitrogen solution (standard liquid) of which the concentration of nitrate nitrogen was 50 mg/L (50 ppm), and thus, the nitrate nitrogen adsorbing ability of the above described carbon material 37 was checked, where  $\text{CaCl}_2$  solutions of which the concentrations were 1 weight %, 3 weight %, 5 weight %, 7 weight %, 10 weight %, 12 weight %, 14 weight %, 17 weight % and 20 weight % were used as the above described  $\text{CaCl}_2$  solution M. Here, the amount of carbon material 37 which was added to each solution was 200 mg. In addition, for comparison, 200 mg of carbon material 37, which was gained by immersing ligneous chips 2 in 10 weight % of  $\text{CaCl}_2$  solution M, and after that, heating and carbonizing the chips for one hour at  $700^\circ\text{C}$ , and then carrying out an HCl process, was used so that the nitrate nitrogen adsorbing ability thereof was checked. The results of the above described test are shown in Fig. 19.

**[0143]**

As is clear from the results shown in Fig. 19, the anion adsorbing ability of carbon material 37 does not increase in proportion to the concentration of the  $\text{CaCl}_2$  solution, and it can be said that it is most preferable for the concentration to be approximately 10 weight % when taking cost and the like into consideration. In addition, it can be seen from the results shown in this-Fig. 19 that it is better to carry out an HCl process on carbon material 37 in order to enhance the anion adsorbing ability of carbon material 37.

**[0144]**

Next, the restoration test, in which carbon material 37 that had been used to adsorb nitrate nitrogen was restored using a KCl (or NaCl) solution and which was carried out to check the nitrate nitrogen adsorbing ability of the restored carbon material 37, is described.

**[0145]**

First, 200 mg of  $\text{CaCl}_2$  charcoal, which had been gained by immersing ligneous chips 2 in a  $\text{CaCl}_2$  solution of 10 weight %, and after that, heating and carbonizing the chips for one hour at  $70^\circ\text{C}$ , was prepared as carbon material 37. Then, this  $\text{CaCl}_2$  charcoal was put in 50 mL of a nitrate nitrogen solution (standard liquid) of which the concentration of nitrate nitrogen was 50 mg/L (50 ppm), and the container was shaken for ten hours under the conditions of 200 rpm at  $20^\circ\text{C}$ , and after that, the concentration of the nitrate nitrogen in the above described standard liquid was measured and the amount of nitrate nitrogen adsorbed by the above described  $\text{CaCl}_2$  charcoal was calculated (initial time).

**[0146]**

Subsequently, the above described  $\text{CaCl}_2$  charcoal was washed with a KCl (or NaCl) solution of 1 mol/L, and furthermore, it was washed with water and then restored. After that, the restored  $\text{CaCl}_2$  charcoal was put in a newly prepared standard liquid (that is to say, 50 mL of a nitrate nitrogen solution of which the concentration of nitrate nitrogen was 50 mg/L), and the container was shaken for ten hours under the conditions of 200 rpm at  $20^\circ\text{C}$ , and after that, the concentration of nitrate nitrogen in the above described standard liquid was measured and the amount of nitrate nitrogen adsorbed by the above described  $\text{CaCl}_2$  charcoal was calculated. In addition, the process, starting from the restoration of this  $\text{CaCl}_2$  charcoal up to the

calculation of the amount of nitrate nitrogen adsorbed by the  $\text{CaCl}_2$  charcoal, was carried out three times in total (first restoration time to third time).

**[0147]**

The results of the above described restoration test, that is to say, the amount of nitrate nitrogen adsorbed by the  $\text{CaCl}_2$  charcoal, was as follows:

Initial time	9.5 mg/g
First restoration time	9.0 mg/g
Second restoration time	9.1 mg/g
Third restoration time	8.8 mg/g

**[0148]**

It was confirmed from the above description that carbon material 37 ( $\text{CaCl}_2$  charcoal), which had been used to adsorb nitrate nitrogen, was restored when washed with a dense KCl (or NaCl) solution, and furthermore, it was subsequently washed with water. This is considered to be because nitrate nitrogen was removed from the  $\text{CaCl}_2$  charcoal when the  $\text{CaCl}_2$  charcoal, which had adsorbed nitrate nitrogen, was washed with a KCl (or NaCl) solution, and furthermore, it was washed with water, and  $\text{Cl}^-$  combined with the functional groups instead of ~~this~~the removed nitrate nitrogen. In addition, it was confirmed from the results of the above described restoration test that carbon material 37 ( $\text{CaCl}_2$  charcoal) could be used a number of times to adsorb nitrate nitrogen in the case where the carbon material was restored by washing it with a KCl (or NaCl) solution, and then washing it with water. Here, the restoring principle is the same in the case where the above described carbon material 37 ( $\text{CaCl}_2$  charcoal) is used to adsorb nitrite nitrogen.

**[0149]**

Next, HCl processed  $\text{CaCl}_2$  charcoal, which had been gained by immersing ligneous chips 2 in a  $\text{CaCl}_2$  solution of 10 weight %, and after that, heating and carbonizing the chips for one hour at ~~70~~700°C, and then, processing the chips through the immersion in an HCl solution of 5 mol/L, was used as carbon material 37, and the results of the restoration test, which was carried out in the same manner as described above on this HCl processed  $\text{CaCl}_2$  charcoal, are shown as follows.

**[0150]**

The results of the above described restoration test, that is to say, the amount of nitrate nitrogen adsorbed by the HCl processed  $\text{CaCl}_2$  charcoal, was as follows:

Initial time	11.0 mg/g
First restoration time	11.0 mg/g
Second restoration time	10.8 mg/g
Third restoration time	10.8 mg/g

It was confirmed from the above description that carbon material 37 (HCl processed  $\text{CaCl}_2$  charcoal), which was gained by processing the chips after carbonization through immersion in an HCl solution, was also restored by washing it with a dense KCl (or NaCl) solution, and furthermore, washing it with water after it was used to adsorb nitrate nitrogen. In addition, it was confirmed that the nitrate nitrogen adsorbing ability of the HCl processed  $\text{CaCl}_2$  charcoal, which increased by processing the charcoal through immersion in an HCl solution, was maintained (kept increasing) even when the HCl processed  $\text{CaCl}_2$  charcoal was repeatedly restored by washing it with a KCl (or NaCl) solution, and then washing it with water.

**[0151]**

Next, the test which was carried out in order to check the fluoride ion adsorbing ability of the above described carbon material 37 is described. First, in order to carry out this test, one set of samples (1) to (7), which were the same as those used in the above described test of nitrate nitrogen and nitrite nitrogen adsorption ability, and of which the total number of samples was 7 with each having 50 mg, was prepared. Then, these samples were individually put into 50 mL of a solution (standard liquid) of which the concentration of fluoride ions was 50 mg/L (50 ppm), and the containers were shaken for ten hours under the conditions of 200 rpm at 20°C, and after that, each concentration of fluoride ions in the standard liquid was measured, and the amount of fluoride ions adsorbed by each sample was calculated.

**[0152]**

Fig. 20 shows the results of a comparison ~~in~~of the fluoride ion adsorbing ability among the respective samples which were gained in the above described test. It can be seen from the results shown in this figure **Fig. 20** that the samples of the present invention all had a high fluoride ion adsorbing ability. Furthermore, the amount of fluoride ions adsorbed by the  $\text{BaCl}_2$

charcoal of (4) and the amount of fluoride ions adsorbed by the HCl processed  $\text{BaCl}_2$  charcoal of (5) are compared, and in addition, the amount of fluoride ions adsorbed by the  $\text{CaCl}_2$  charcoal of (6) and the amount of fluoride ions adsorbed by the HCl processed  $\text{CaCl}_2$  charcoal of (7) are compared, and thereby, it can be seen that it is better to carry out a process (HCl process) of immersing carbon material 37 in an HCl solution in order to enhance the fluoride ion adsorbing ability of carbon material 37. However, carbon material 37, having a sufficiently high fluoride ion adsorbing ability, can be gained without carrying out an HCl process, and in this case, carbon material 37 can be manufactured at a cost that is lower by the portion for carrying out a process for contacting the carbon material with an HCl solution.

**[0153]**

Next, the restoration test, in which carbon material 37 that had been used to adsorb fluoride ions was restored using a hydrochloric acid (or sulfuric acid) and which was carried out to check the fluoride ion adsorbing ability of the restored carbon material 37, is described.

**[0154]**

First, 200 mg of  $\text{CaCl}_2$  charcoal, which had been gained by immersing ligneous chips 2 in a  $\text{CaCl}_2$  solution of 10 weight %, and after that, heating and carbonizing the chips for one hour at ~~70~~700°C, was prepared as carbon material 37. Then, this  $\text{CaCl}_2$  charcoal was put in 50 mL of a solution (standard liquid) of which the concentration of fluoride ions was 50 mg/L (50 ppm), and the container was shaken for ten hours under the conditions of 200 rpm at 20°C, and after that, the concentration of the fluoride ions in the above described standard liquid was measured and the amount of fluoride ions adsorbed by the above described  $\text{CaCl}_2$  charcoal was calculated (initial time).

**[0155]**

Subsequently, the above described  $\text{CaCl}_2$  charcoal was washed with a hydrochloric acid (or sulfuric acid) of 1 mol/L, and furthermore, it was washed with water and then restored. After that, the restored  $\text{CaCl}_2$  charcoal was put in a newly prepared standard liquid (that is to say, 50 mL of a solution of which the concentration of fluoride ions was 50 mg/L), and the container was shaken for ten hours under the conditions of 200 rpm at 20°C, and after that, the concentration of fluoride ions in the above described standard liquid was measured and the amount of fluoride ions adsorbed by the above described  $\text{CaCl}_2$  charcoal was calculated. In

addition, the process, starting from the restoration of this  $\text{CaCl}_2$  charcoal up to the calculation of the amount of fluoride ions adsorbed by the  $\text{CaCl}_2$  charcoal, was carried out three times in total (first restoration time to third time).

**[0156]**

The results of the above described restoration test, that is to say, the amount of fluoride ions adsorbed by the  $\text{CaCl}_2$  charcoal, was as follows:

Initial time	22.5 mg/g
First restoration time	22.4 mg/g
Second restoration time	21.7 mg/g
Third restoration time	21.9 mg/g

It was confirmed from the above description that carbon material 37 ( $\text{CaCl}_2$  charcoal), which had been used to adsorb fluoride ions, was restored when washed with a dense hydrochloric acid (or sulfuric acid), and furthermore, it was washed with water. This is considered to be because fluoride ions were removed from the  $\text{CaCl}_2$  charcoal when the  $\text{CaCl}_2$  charcoal, which had adsorbed the fluoride ions, was washed with a hydrochloric acid (or sulfuric acid), and furthermore, it was washed with water, and  $\text{Cl}^-$  (or  $\text{SO}_4^{2-}$ ) combined with the functional groups instead of these removed fluoride ions. In addition, it was confirmed from the results of the above described restoration test that carbon material 37 ( $\text{CaCl}_2$  charcoal) could be used a number of times to adsorb fluoride ions in the case where the carbon material was restored by washing it with a hydrochloric acid (or sulfuric acid), and then washing it with water.

**[0157]**

Next, HCl processed  $\text{CaCl}_2$  charcoal, which had been gained by immersing ligneous chips 2 in a  $\text{CaCl}_2$  solution of 10 weight %, and after that, heating and carbonizing the chips for one hour at  $700^\circ\text{C}$ , and then, processing the chips through the immersion in an HCl solution of 5 mol/L, was used as carbon material 37, and the results of the restoration test, which was carried out in the same manner as described above on this HCl processed  $\text{CaCl}_2$  charcoal, are shown as follows.

**[0158]**

The results of the above described restoration test, that is to say, the amount of fluoride ions adsorbed by the HCl processed  $\text{CaCl}_2$  charcoal, was as follows:

Initial time	32.0 mg/g
First restoration time	31.5 mg/g
Second restoration time	31.4 mg/g
Third restoration time	31.2 mg/g

It was confirmed from the above description that carbon material 37 (HCl processed  $\text{CaCl}_2$  charcoal), which was gained by processing the chips after carbonization through immersion in an HCl solution, was also restored by washing it with a dense hydrochloric acid (or sulfuric acid) solution, and furthermore, washing it with water after it was used to adsorb fluoride ions. In addition, it was confirmed that the fluoride ion adsorbing ability of the HCl processed  $\text{CaCl}_2$  charcoal, which increased by processing the charcoal through immersion in an HCl solution, was maintained (kept increasing) even when the HCl processed  $\text{CaCl}_2$  charcoal was repeatedly restored by washing it with a hydrochloric acid (or sulfuric acid), and then washing it with water.

#### **[0159]**

An anion adsorbing carbon material according to this invention adsorbs anions such as nitrate nitrogen, nitrite nitrogen and fluorine, and therefore, can be mainly used in the applications, for example, as follows:

#### **[0160]**

##### **(1) Purifier for Processing Sewage and Groundwater**

Currently, most of the nitrate nitrogen components such as nitrite ions and nitrate ions as well as fluoride ions which exist in processed sewage water and groundwater are discharged without being treated. An anion adsorbing carbon material of this invention can be used as an inexpensive and effective purifier for processing sewage and groundwater. In a sewage treatment plant or a groundwater purifying plant, a purifier for processing sewage having an appropriate size, for example, is floated in the sewage or is contained in a cage having an appropriate mesh size or a mesh bag so as to be installed in a state of making sufficient contact with the water to be treated, and thereby, anions such as nitrite ions, nitrate ions and fluoride ions that are included in the water to be treated are adsorbed without fail. In addition, in the case where the purifier is in powder form, this may be stuck or embedded to an unwoven cloth.

#### **[0161]**

##### **(2) Purifier for Treating Discharged Wastewater**



Currently, there are only a few inexpensive materials which adsorb anions such as nitrite ions and nitrate ions that are included in wastewater from chemical factories, oil purifying factories, steel and steel material manufacturing factories, paper manufacturing factories, semiconductor factories, industrial waste storage facilities, spinning factories in the fiber manufacturing industry and food processing factories, as well as fluoride ions that are included in wastewater from factories, residential wastewater of homes, combined treatment septic tanks and communities, and wastewater from the glass, plating, metal scouring, metal surface processing, and ceramics industries, electronic industries including semiconductors, chemical industries and the like. An anion adsorbing carbon material of this invention can be used as an inexpensive and effective purifier for processing discharged wastewater.

**[0162]**

In a discharge wastewater path or within a tank for processing discharged wastewater from the residential wastewater of each home, a combined treatment septic tank, a community, or in a discharge wastewater path and within a tank for processing discharged wastewater where wastewater from livestock farms and various types of factories flows, a purifier for processing sewage having an appropriate size, for example, is floated in the discharged wastewater or is contained in a cage having an appropriate mesh size or a mesh bag so as to be installed in a state of making sufficient contact with the water to be treated, and thereby, anions such as nitrite ions, nitrate ions and fluoride ions that are included in the water to be treated are adsorbed without fail. In addition, in the case where the purifier is in powder form, this may be stuck to an unwoven cloth.

**[0163]**

**(3) Purifier for Tap Water**

In recent years and in many regions, a severe groundwater contamination of nitrite ions and nitrate ions, which has been caused by discharged wastewater as described in (2) and a large amount of fertilizers used in tea fields, turfs for golfing and the like, as well as a large amount of excrement from livestock on farm grounds, has been observed, and thus, it has become necessary to remove nitrate nitrogen components from the collected water when the water is used as a water source for tap water, including water from rivers. An anion adsorbing carbon material of this invention can be used as an inexpensive and effective purifier for tap water.

**[0164]**

In a facility for purifying tap water from a reservoir, within a facility for collecting river water and groundwater or within a home water purifier, a purifier for processing tap water having an appropriate size, for example, is floated in the tap water or is contained in a cage having an appropriate mesh size or a mesh bag so as to be installed in a state of making sufficient contact with the water to be treated, and thereby, anions such as nitrite ions, nitrate ions and fluoride ions that are included in the water to be treated are adsorbed without fail. In addition, in the case where the purifier is in powder form, this may be stuck to an unwoven cloth.

**[0165]**

**(4) Purifier for Farmlands**

In many regions, a severe underground contamination of nitrite ions and nitrate ions, which has been caused by a large amount of fertilizers used in tea fields or a large amount of excrements from livestock on farms, has been observed. An anion adsorbing carbon material of this invention can be used as an inexpensive and effective purifier for farmlands.

**[0166]**

A purifier for farmlands having an appropriate size for example, is mixed with the soil of farmlands or buried deep into the soil of farmlands, and thereby, nitrite ions and nitrate ions which originate from excessive fertilizers or excrements from livestock can be adsorbed, and thus, the amount of nitrite ions and nitrate ions which flow into underground water can be reduced. Furthermore, this purifier for farmlands is effective as a material for physically improving the soil, and in addition, the adsorbed nitrite ions and nitrate ions can be used by plants, and therefore, this purifier for farmlands functions as a fertilizer having gradual effects. Accordingly, the anion adsorbing carbon material of this invention, which has adsorbed nitrite ions and nitrate ions, can be used as a soil improving fertilizer.

**[0167]**

**(5) Purifier for Tank Water and Culture Ponds**

In the tank water of a tank for breeding creatures (for example, a tank in an aquarium and a tank for a business or a home) where aquatic creatures and amphibians are bred as well as in a culture pond for fish or shrimps, excrements from the creatures and uneaten food generate ammonia, which is then oxidized so as to be converted to nitrite ions or nitrate ions, and when the concentration of these is high, poisoning symptoms may appear in the creatures that are

being bred, though the toxicity thereof is gradually reduced. An anion adsorbing carbon material of this invention can be used as an inexpensive and effective purifier for tank water.

**[0168]**

Within a water tank or a culture pond or within a purifier for the water in a water tank or a culture pond, a purifier for tank water and culture ponds having an appropriate size, for example, is floated in the water to be treated or is contained in a cage having an appropriate mesh size or a mesh bag so as to be installed in a state of making sufficient contact with the water to be treated, and thereby, anions such as nitrite ions, nitrate ions and fluoride ions that are included in the water to be treated are adsorbed without fail. In addition, in the case where the purifier is in powder form, this may be stuck to an unwoven cloth.

**[0169]**

**Industrial Applicability**

An anion adsorbing carbon material according to the present invention adsorbs nitrate nitrogen and nitrite nitrogen, and therefore, can be applied to purification of water, prevention of contamination caused by the livestock industry, and prevention of contamination caused by excessive fertilizing in agriculture. In addition, an anion adsorbing carbon material according to the present invention adsorbs fluorine, and therefore, can be applied in final treatment installations in semiconductor factories, glass factories, plating factories and the like, where cleaning is carried out using hydrofluoric acid.

**[0170]**

**Those skilled in the art will appreciate that various adaptations and modifications of the just-described preferred embodiment can be configured without departing from the scope and spirit of the invention. Therefore, it is to be understood that, within the scope of the amended claims, the invention may be practiced other than as specifically described herein.**